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# (54) Method for driving LCD modules with scale of greys by PWM technique and reduced power consumption

(57) Herein described is a driving method for LCD modules having a multiplicity of display elements placed in the intersections of a matrix having a plurality of row electrodes and a plurality of column electrodes. The method comprises a first phase for scanning all the row electrodes of said matrix in an interval of scanning time (NT). The first phase comprises a second phase comprising the generation of a first signal suited to energizing at least one row electrode of the matrix for a first preset interval of time (T), the generation of second signals (C3(t), C5(t)) suited to energizing respectively each column electrode of said matrix simultaneously with the energizing of at least one row electrode. The second signals (C3(t), C5(t)) are suited to determining the grey level of each display element of at least one row electrode energized by means of an altemance of corresponding values distinct signal levels (Von, Voff, V1-V3) for intervals of time (T1on, T1off) comprised in the first preset interval of time (T) by means of a first PWM modulation. The first preset interval of time (T) is lower than the interval of scanning time (NT). The first phase comprises a third phase successive to the second phase and comprising the generation of another first signal suited to energizing at least another row electrode of said matrix for a second preset period of time (T) equal and successive to the first preset interval of time, the generation of third signals (C3(t), C5(t)) suited to energizing each column electrode of the matrix simultaneously to said at least another row electrode; the third signals are suited to determining the grey level of each display element of at least another row electrode energized by means of an altemance of values corresponding to said distinct signal levels (Von, Voff, V1-V3) for intervals of time (T2on, T2off) comprised in said second preset interval of time (T) by means of a second PWM modulation. The second PWM modulation is such to ensure the continuity of the signal level of said second signals (C3(t), C5 (t)) and third signals (C3(t), C5(t)) in the passage from the first preset period of time (T) to the second preset period of time (T). (Figure 5).

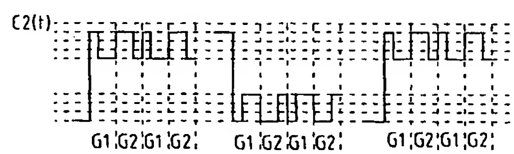


Fig.4

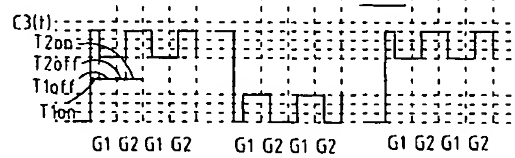


Fig5

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## Description

**[0001]** The present invention refers to a driving method for grey scale LCD modules by means of PWM technique.

**[0002]** By LCD module it is meant a visualizing device or LCD (Liquid Crystal Display) display basically made up of a matrix of electrodes in rows and columns which, suitably driven by application of a voltage signal, determine at the crossing points the so-called pixels, a modification in optic behavior of the liquid crystal interposed.

**[0003]** A method that is often used for driving an LCD and known as Improved Alt & Pleshko (IA&P), requires the energizing of a single electrode per row for an elementary time period by means of a single selection impulse and the simultaneous energizing of the column electrodes; values of voltage are applied to the latter which are suited for determining the turning on or off of all the pixels that belong to that single row. For a successive elementary time period another row electrode will be energized and so on, until the scanning of the final row electrode is completed; therefore if the row electrodes are a number N and T is the elementary time period, the time needed for scanning all the rows will be given by NT which is also called "frame".

**[0004]** Another method used for driving an LCD and known as Multi-Line Addressing, requires the simultaneous energizing of more than a single row electrode, by means of selection impulses prolonged for an interval of time which is basically the same as the interval of time T of the Improved Alt & Pleshko drive, multiplied by the number of rows simultaneously energized and the simultaneous energizing of the column electrodes; values of voltage are applied to the latter which are suited for determining the turning on or off of all the pixels that belong to the rows energized simultaneously.

**[0005]** Considering that for a pixel the determination of the white and the black varies by applying two different levels of voltage respectively to the pixel, an effective connecting voltage (Von) and an effective disconnecting voltage (Voff), the generation of the levels of intermediate grey between the Von and Voff voltages is determined by applying intermediate levels of effective voltage between Von and Voff to the pixel. As can be seen in Figure 1, with the increase in the effective voltage applied Ve, the transmittance Tr of the pixel is reduced visualizing darker grey shades.

**[0006]** To obtain intermediate values of effective voltage corresponding to the grey levels required, only the waveform of the voltage signal applied to the columns should be modulated as the voltage signals applied to the rows do not participate in determining the grey levels.

**[0007]** Should a pulse width modulation (PWM) be used for the waveforms of the voltage signals applied to the columns, it requires different commutations between the levels of voltage Von and Voff to obtain the grey levels of required. This can be seen in Figures 2a-2c, which show the graphs of the waveforms of a voltage signal C1(t) applied to a column of a matrix of an LCD for determining two grey levels G1 and G2 as well as the white value W and black B according to the Improved Alt & Pleshko drive, in the various cases of modulation in width (Figure 2a), in frequency (Figure 2b) and in width of impulse (PWM) (Figure 2c). The number of commutations of the waveforms of the signals applied to the columns for the case of pulse width modulation (PWM) (Figure 2c) is greater in relation to the modulations in frequency (Figure 2b) or in width (2a).

**[0008]** With the increase in the number of commutations the consumption of current increases, for the quantity of load that is transferred in the unit of time to the pixel.

**[0009]** In addition to an increase in consumption, a high number of commutations also determines an effect of "cross-talk", due to an increase in the overall quantity of load that is transferred on the adjacent pixels instead of on the pixel of destination. This is due to various factors: to the fact that a deformation of the waveform of the approximately exponential type is associated to every transition , to the fact that the queue of a row pulse in a period of elementary time T is partially overlapped to the column pulses of the successive period of time T, to the transient induced by the commutations of the row electrodes on the column electrodes. The cross-talk effect entails a reduction in contrast in the LCD and a reduction of the ratio between the transmittance of the pixel that are on and that of the pixel that are off, with consequent reduction of the contrast.

**[0010]** In addition, given that the mixtures used in the LCDs have an optic behavior that generally depends on the frequency of the signal applied, the high number of commutations determines a further reduction of the contrast and a unevenness of visualization due to the modulation of the characteristic transmittance/effective voltage.

**[0011]** In view of the state of the technique described, the object of the present invention is to present a driving method for grey scale LCD modules by means of PWM technique that minimizes the above described problems.

**[0012]** In accordance with the present invention, said object is reached by means of a method for driving LCD modules having a multiplicity of display elements placed in the intersections of a matrix having a plurality of row electrodes and a plurality of column electrodes, said method comprising a phase for scanning all the row electrodes of said matrix in an interval of scanning time, said phase comprising at least a first and a second successive phase both comprising the generation of a first signal suited for energizing at least one row electrode of said matrix for a preset interval of time less than said scanning time, the generation of second signals suited for energizing respectively each column electrode of said matrix simultaneously with the energizing of said at least one row electrode, said second signals being suited for determining the grey level of each display element of at least one row electrode energized by means

of an alternance of values corresponding to distinct signal levels for intervals of time included in said preset interval of time by means of a PWM for each phase of said at least a first and a second phase, characterized in that said PWM is such that it ensures the continuity of the level of signal of said second signals in the passage from said first phase to said second phase.

**[0013]** Thanks to the present invention, it is possible to execute a driving method for grey scale LCD modules by means of PWM technique that attenuates the problems of current consumption and of reduction of contrast existing in the known methods of driving LCDs.

**[0014]** The characteristics and the advantages of the present invention will be evident from the following detailed description of an embodiment thereof, illustrated as non-limiting example in the enclosed drawings, in which:

Figure 1 is a graph of the transmittance of a pixel in function of the effective voltage applied to a column;
Figures 2a-2c are graphs of the waveforms of a voltage signal applied to a column of a matrix of an LCD for determining two grey levels G1 and G2 with a modulation in width (Figure 2a), in frequency (Figure 2b), and PWM (Figure 2c) according to an Improved Alt & Pleshko drive;
Figure 3 shows four possible solutions for the PWM of the waveform of a voltage signal applied to a column of a matrix of an LCD for determining a grey level;
Figure 4 is a graph of a waveform of a voltage signal applied to a column of a matrix of an LCD for determining two grey levels G1 and G2 according to an Improved Alt & Pleshko drive and modulated with a known PWM;
Figure 5 is a graph of a waveform of a voltage signal applied to a column of a matrix of an LCD for determining two grey levels G1 and G2 according to an Improved Alt & Pleshko drive and modulated with a PWM according to the invention;
Figure 6 is a graph of a waveform of a voltage signal applied to a column of a matrix of an LCD for determining two grey levels G1 and G2 according to Multi-Line Addressing drive and modulated with a known PWM;
Figure 7 is a graph of a waveform of a voltage signal applied to a column of a matrix of an LCD for determining two grey levels G1 and G2 according to Multi-Line Addressing drive and modulated with a PWM according to the invention;
Figure 8 shows the waveforms relative to the row selection signals for the four rows selected Row0-Row3 and the matrix R of the row patterns corresponding to signals Row0-Row3;
Figure 9 is a matrix diagram for obtaining the values of signal voltage of voltage C5(t) of Figure 7 starting from the matrix of row R and the matrix of information I;
Figure 10 is a circuit block diagram that implements the method drive with a PWM of the waveforms of the voltage signals applied to the columns according to the invention.

**[0015]** With reference to Figure 3, four possible solutions are shown, indicated by the numbers 10, 20, 30 ,40 for the PWM of the waveform of a voltage signal applied to a column of a matrix of an LCD for determining a grey level. If Vg is the voltage value between the values Voff and Von and corresponding to the grey level required, there is an infinite number of solutions that permit such value to be reached through a balance of the times of a period T in which the voltages Voff and Von are applied alternately.

**[0016]** Among the infinite number of solutions that permit such value to be reached through a balance of the times, only two, indicated with the numbers 10 and 40, require only one commutation. Therefore the voltage value Vg will be given by:

$$Vg=Voff + x^{*}(Von-Voff) \text{ with x belonging to the interval } (0, 1)$$

**[0017]** And the values of the times Toff and Ton in which the voltages Voff and Von are applied are given by :

$$Toff=(1 - x)^{*}T \text{ and } Ton=x^{*}T.$$

**[0018]** The basic idea of the invention consists of using both the above described modulation modalities (indicated with 10 and 40 in Figure 3) alternating the use after P intervals of time T, with P whole number and less than N, preferably with P=1, that is after each interval of time T of the frame NT.

**[0019]** An implementation of the invention is shown in Figure 5. In fact it shows a graph of a waveform of a voltage signal C3(t) applied to a column of a matrix of an LCD for determining two grey levels G1 and G2 with a drive of rows according to the Improved Alt & Pleshko method and modulated with a PWM according to the invention; the grey levels G1 and G2 are obtained by means of the voltage values Voff and Von for respective periods of time T1off, T2off and T1on, T2on. For the first row of the matrix, the waveform of the column signal is controlled for the determination of the

grey level G1, so that a first period of time T1on in which the signal is at a voltage value Von is followed by a period of time T1off in which the signal is at a voltage value Voff; the waveform of the column signal for the second row of the matrix is controlled so that for the determination of the second grey level G2 in a first period of time T2off it assumes the voltage value Voff and in the successive period of time T2on it assumes the value Von. The above is repeated for the rows following the second.

**[0020]** Figure 4 shows a graph of a waveform of a voltage signal C2(t) applied to a column of a matrix of an LCD for determining two grey levels G1 and G2 according to an Improved Alt & Pleshko drive and modulated with a known PWM. In such case for the first row of the matrix, the waveform of the column signal is controlled for the determination of the grey level G1, so that a first period of time T1on in which the signal is at a voltage value Von is followed by a period of time T1off in which the signal is at a voltage value Voff; the waveform of the column signal for the second row of the matrix is controlled so that for the determination of the second grey level G2 it assumes in a first period of time T2on the voltage value Von and in the successive period of time T2off it assumes the value Voff and so on for the rows following the second. Therefore it can be observed that, independently from the grey level required, the overall number of commutations needed to produce the waveform of the voltage signal of Figure 5 is lower than the voltage signal of Figure 4 in a scanning interval. In the case in which the PWM modulation modalities are alternated after each interval of time T, the decrease of the commutations compared to the known art in the case of a scanning interval NT is 50%.

**[0021]** In the case of Multi-Line Addressing given that more than one row electrode is energized simultaneously, the voltage values that have to be supplied to each column electrode will depend on the state of all the pixels belonging to the column electrode and to the rows energized simultaneously.

**[0022]** Figure 7 shows a graph of a waveform of a voltage signal C5(t) applied to a column of a matrix of an LCD for determining four distinct grey levels according to Multi-Line Addressing drive of 4 rows simultaneously and modulated with a PWM according to the invention. Figure 7 shows the waveforms, corresponding to 4 distinct grey levels, of the voltage signals $C5^{I}$ (t)-$C5^{IV}$(t) which should be applied to the column electrode in the case in which the 4 rows are scanned one at a time (Improved Alt & Pleshko drive). The waveform of the resulting voltage signal C5(t) in the Multi-Line Addressing case for the column electrode must consider the change of state in the time of the 4 pixels and the overall voltage values applied to the rows. As can be seen from the comparison between the waveform of the voltage signal C5(t) of Figure 7 and the waveform of the voltage signal C4(t) of Figure 6, which is the waveform of a voltage signal applied to a column of a matrix of an LCD for determining four distinct grey levels according to Multi-Line Addressing drive of 4 rows simultaneously and modulated with a known PWM, the number of the commutations in two successive periods of elementary time T is lower for the waveform of the voltage signal C5(t) according to the invention (Figure 7) compared to that known C4(t) (Figure 6) (the commutation to the interface of the two periods of elementary time T is eliminated). Figure 6 shows the waveforms, corresponding to 4 distinct grey levels , of the voltage signals $C4^{I}$(t)-$C4^{IV}$(t) which should be applied to the column electrode in the case in which the 4 rows are scanned one at a time (Improved Alt & Pleshko drive).

**[0023]** Figure 8 shows the waveforms relative to the row selection signals for the four rows selected Row0-Row3 and the matrix R of the row patterns corresponding to signals Row0-Row3 where the periods of time T0-T3 are sub periods of the period of elementary time T.

**[0024]** The waveform of the signal C5(t) in Figure 7 assumes three distinct levels of signal or distinct voltage values V1-V3 (such as the waveform of the signal C4(t) of Figure 6); this is a particular case as said signal can assume various distinct values. Nevertheless with the hypothesis of having a number of rows selected simultaneously equal to 4 and considering the only really feasible solution MLA, that is in the case in which the waveforms applied to the rows define a diagonal matrix or a possible transposition of it (that is in the case in which the patterns that form the matrix R contain only one 0 or only one 1), the column waveform will assume three distinct voltage values which are kept specular passing from a period of elementary time T to a successive one.

**[0025]** In general, the calculation of the column voltages can be expressed as the matrix product between the transposing of a matrix of information and the matrix R of the row patterns. The information matrix is the matrix consisting of the patterns of information that define the on/off state of the pixels; in the case of 4 rows and 1 column we will have a matrix of information I that indicates the on/off state of the corresponding 4 pixels, indicating with 1 and 0 the on and off state of the pixels (on the LCD screen the on state and the off state are visualized respectively with a white pixel and a black one or vice versa).

**[0026]** More simply the voltage values that the column signal assumes in each period of elementary time T is given by the difference between the column patterns of a matrix of information I memorized, in which the patterns of information are placed in columns, and the column patterns of the matrix of row R. Therefore, as shown in Figure 9, the voltage values assumed by the signal C5(t) are given by the differences between the column patterns of the matrix I and the first column pattern of the matrix R. Assuming that the value of the differences between the above-mentioned patterns is directly proportional to the voltage levels of the signal C5(t), we have that considering the first pattern of information [1 1 1 1] and the first column pattern of the matrix R [0 1 1 1] there is only one difference and therefore the

voltage value is V1, considering the second pattern of information [1 1 0 1] and the first column pattern of the matrix R [0 1 1 1] there are two differences and therefore the voltage value is V2, considering the third pattern of information [1 0 01] and the first column pattern of the matrix R [0 1 1 1] there are three differences and therefore the voltage value is V3 and so on.

**[0027]** The image on the LCD screen is obtained in the following manner; in correspondence with each row pattern ( that value that in a certain moment the four rows have applied), the column signal is such to make a contribution of effective voltage, to the pixel, which fixes its state at white, black or intermediate grey.

**[0028]** With the method according to the invention we have a noticeable reduction in consumption of current that can reach up to 33% for the case of Multi-Line Addressing or up to 50% for the case of Improved Alt & Pleshko.

**[0029]** Figure 10 shows a possible example of circuit block diagram that implements the drive method with a PWM of the waveforms of the voltage signals applied to the columns according to the invention.

**[0030]** The circuit diagram of Figure 10 comprises the multiplexers 1, 2, 8, a counter register 3, comparators 4 and 7, the synchronous flip-flops 5 and 6 and an adding/subtracting block 9. The circuit functions as follows.

**[0031]** Indicating with M the maximum number of pulses in which the period of elementary time T can be divided (that is the maximum number of the grey levels that can be obtained) the number of pulses of the period of time T that represent the grey level required (with $Q<M$)can be defined with Q.

**[0032]** After the initialization of the circuit the counter register 3 is loaded to the value 0 by means of the multiplexers 1 and 2; the synchronous flip-flop 6 transmits a command signal to the blocks 1, 8 and 9 so that the multiplexers 1 and 8 let the value M pass and the block 9 acts as adder and adds a unit U to the data in output to the register 3 and transmits the new data in input to the multiplexer 2; the output OUT is at the voltage signal level Von. The comparator 7 suited for comparing the value of the data in output to the register 3 with the value M in output to the multiplexer 8, given that the data in output from the register 3 is lower than the value M, transmits a command signal to the multiplexer 2 so that the latter lets the data pass in output to the block 9. After each instant of elementary time, that is after each successive CLOCK strike, the register 3 will increase by a unit because of the multiplexer 2. When the value of the register 3 is equal to Q, the comparator 4 will transmit a command signal to the flip-flop 5 which changing state will make the waveform of the signal of the column electrode commutate from the value Von to the value Voff. The block 3 will continue increasing until it reaches the value Q. When the values of the data in output to the register counter 3 and the data in output to the multiplexer 8 are equal, that is equal to M, the comparator 7 will transmit a command signal to the synchronous flip-flop 6 so as to determine in it a change of state and to the multiplexer 2 so that the latter will let the output of the block 1 pass instead of from block 9. The flip-flop 6 after the change of state commands the multiplexer 1 to let the value 0 pass, the block 9 to act to subtract from the value M and the block 8 to let the value 0 pass. The cycle proceeds as previously described for the successive period of time T, but the level of the voltage signal on the terminal OUT will be initially equal to Voff.

**[0033]** In the case of a color display the previously described technique can be carried out. In fact to obtain a color image in an LCD display three pixels to which the grey scale technique is applied have to be covered with red, green and blue filters; the color is determined by the light intensity of the three pixels covered by the filters.

## Claims

1. Drive method for LCD modules having a multiplicity of display elements placed in the intersections of a matrix having a plurality of row electrodes and a plurality of column electrodes, said method comprising a phase for scanning all the row electrodes of said matrix in an interval of scanning time (NT), said phase comprising at least a first and a successive second phase both comprising the generation of a first signal suited to energizing at least one row electrode of said matrix for a preset interval of time (T) less than said scanning time (NT), the generation of second signals (C3(t), C5(t)) suited to energizing respectively each column electrode of said matrix simultaneously with the energizing of said at least one row electrode, said second signals (C3(t), C5(t)) being suited to determining the grey level of each display element of the at least one row electrode energized by means of an alternance of values corresponding to distinct signal levels (Von, Voff, V1-V3) for intervals of time (T1on, T1off) comprised in said preset interval of time (T) by means of a PWM modulation for each phase of said at least a first and a second phase, **characterized in that** said PWM modulation is such to ensure the continuity of the signal level of said second (C3(t), C5(t)) signals in the passage from said first phase to said second phase.

2. Method according to claim 1, **characterized in that** said PWM modulation of said second signals (C3(t), C5(t)) applied to the column electrodes is such to ensure a number of minimum commutations between the distinct signal levels (Von, Voff, V1-V3) in the preset interval of time (T).

3. Method according to claim 1 or 2, **characterized in that** during said at least a first and a second phase only one

row electrode is energized per phase in said period of time preset (T) and said distinct signal levels are two (Von, Voff).

4. Method according to claim 1 or 2, **characterized in that** during said at least first and second phase more than one row electrode is energized per phase in said period of time preset (T).

5. Method according to claim 1, **characterized in that** said at least one first and second phase alternate with each other for the entire duration of said scanning interval of the rows (NT).

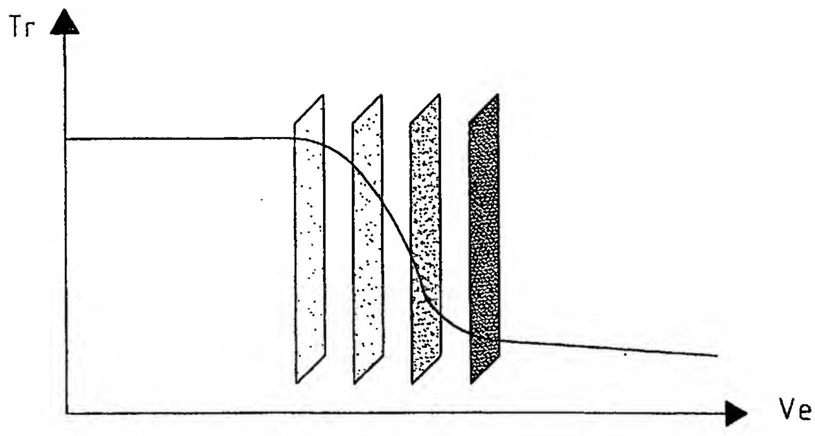



Fig.1

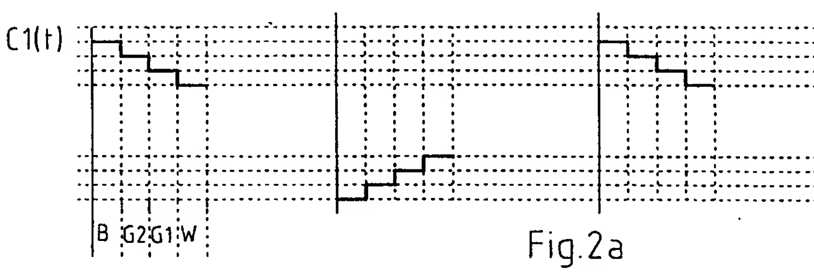



Fig.2a

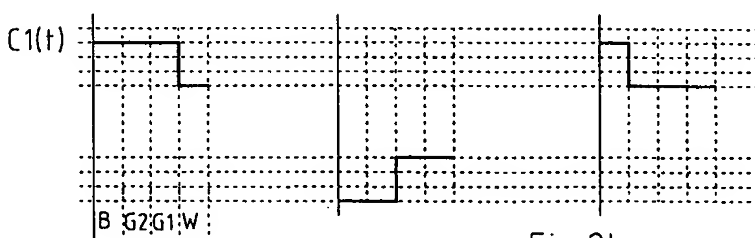



Fig.2b

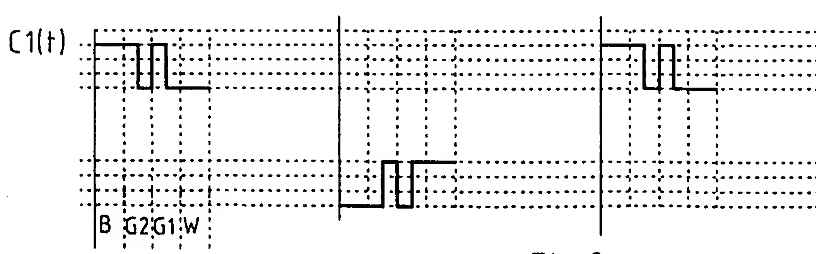



Fig.2c

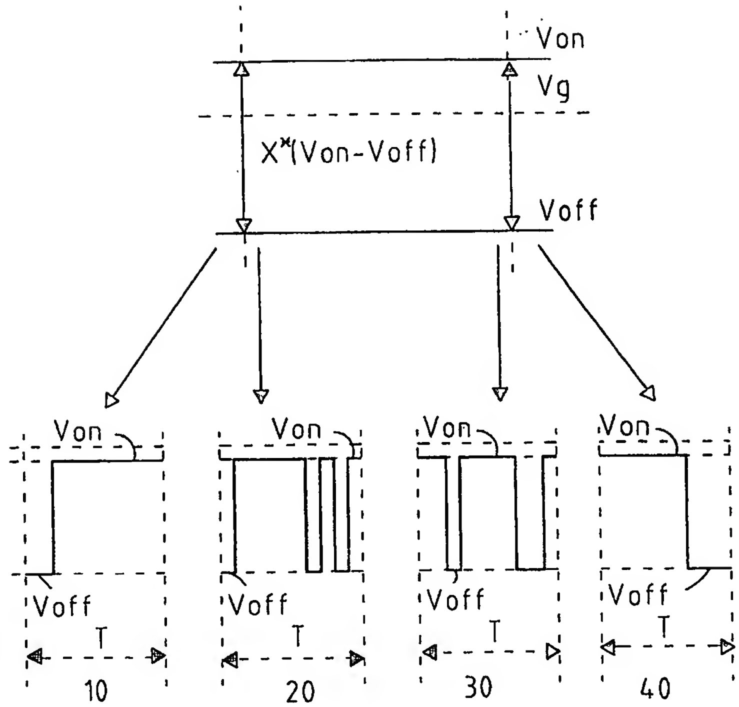



Fig.3

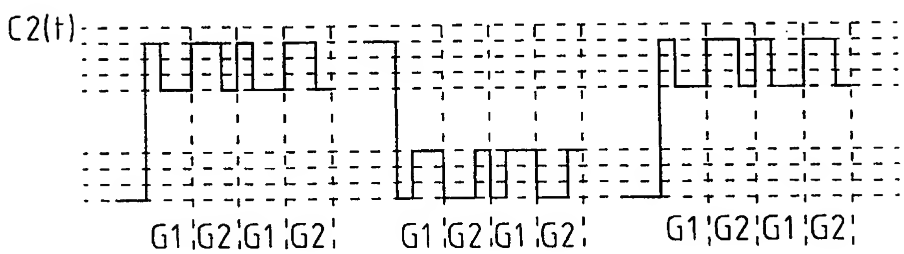



Fig.4

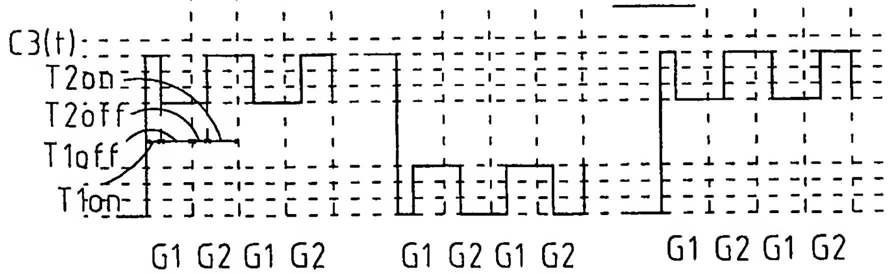



Fig5

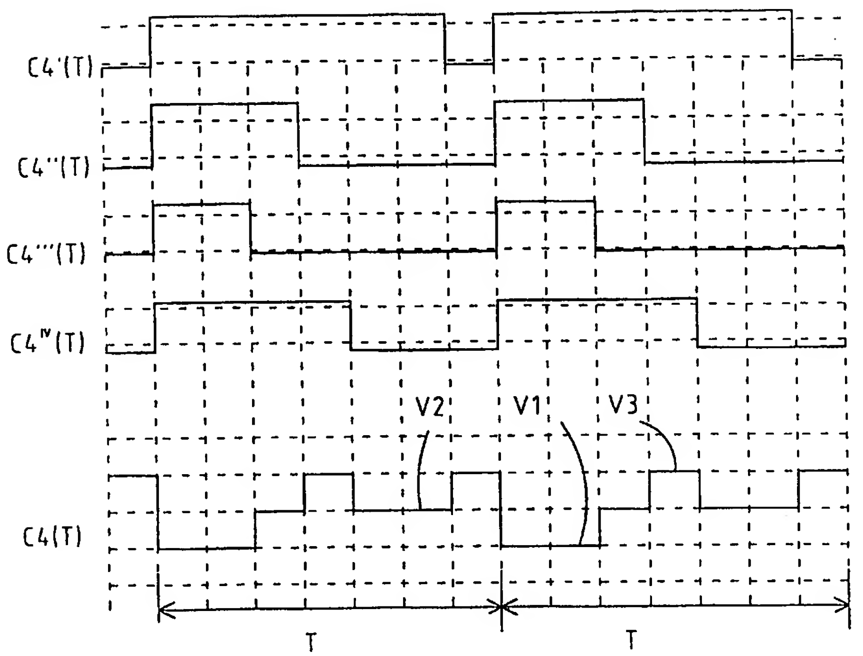

C4'(T)
C4''(T)
C4'''(T)
C4$^{IV}$(T)
V2
V1
V3
C4(T)
T
T

Fig.6

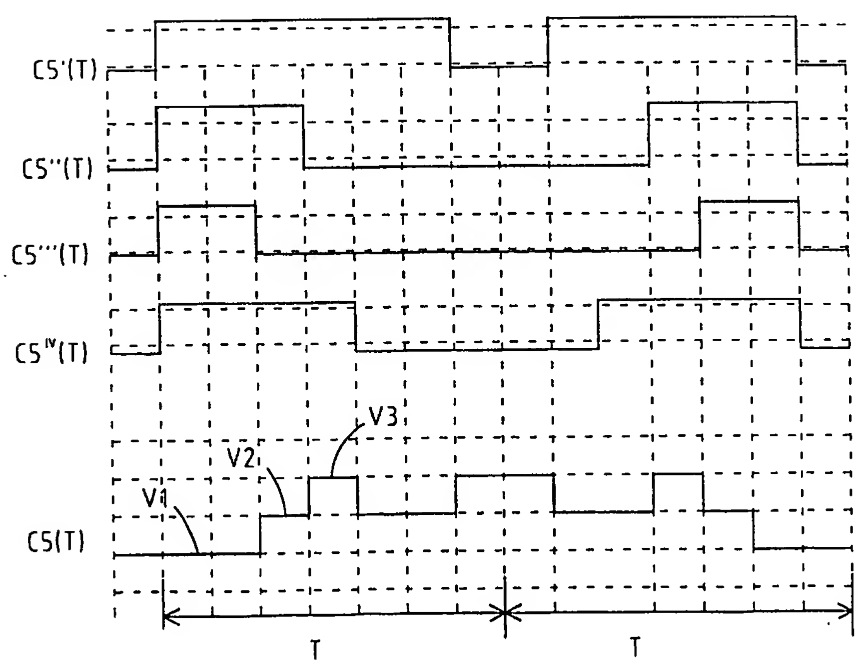
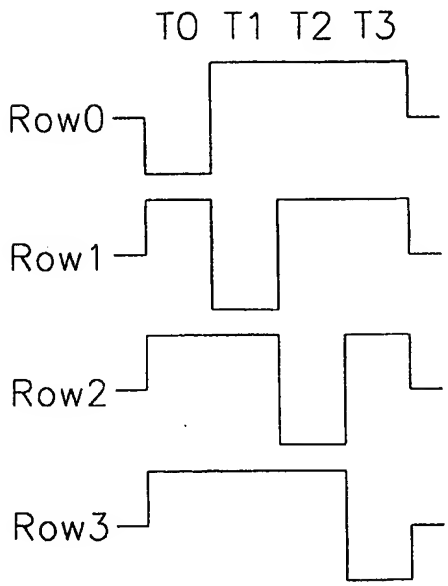

C5'(T)
C5''(T)
C5'''(T)
C5$^{IV}$(T)
V3
V2
V1
C5(T)
T
T

Fig.7




$$R \begin{bmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix}$$

FIG.8

$$R \begin{bmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix} \qquad I \begin{bmatrix} 1 & 1 & 1 & 0 & 0 & \ldots \\ 1 & 1 & 0 & 0 & 0 & \ldots \\ 1 & 0 & 0 & 0 & 0 & \ldots \\ 1 & 1 & 1 & 1 & 0 & \ldots \end{bmatrix}$$

FIG.9

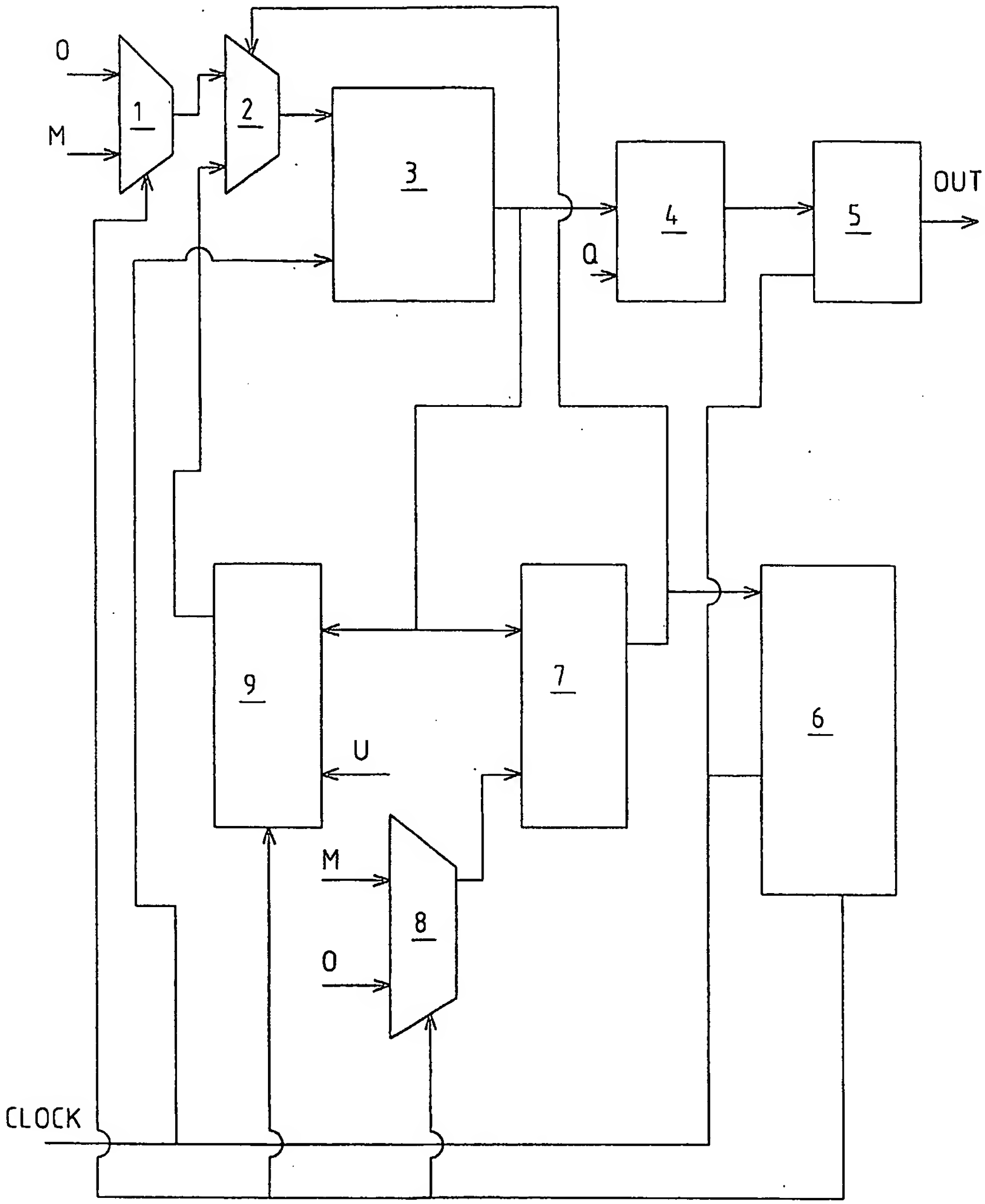



Fig.10

European Patent Office

# EUROPEAN SEARCH REPORT

Application Number
EP 02 42 5109

| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
|---|---|---|---|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.7) |
| X<br><br>Y | WO 00 16305 A (KONINKL PHILIPS ELECTRONICS NV) 23 March 2000 (2000-03-23)<br>* abstract *<br>* page 1, line 7 - page 2, line 15 *<br>* page 3, line 4 - line 7; figure 1 *<br>* page 3, line 21 - page 5, line 9; figures 3-8 *<br>* page 5, line 22 - line 26 *<br>--- | 1-3,5<br><br>4 | G09G3/36 |
| X | PATENT ABSTRACTS OF JAPAN<br>vol. 1999, no. 14,<br>22 December 1999 (1999-12-22)<br>-& JP 11 242465 A (SNK:KK),<br>7 September 1999 (1999-09-07)<br>* abstract; figures 2,4,7,8 *<br>* paragraphs '0010!,'0022!,'0033!,'0036!,'0040!,'0041!,'0051!,'0060!-'0067! *<br>--- | 1-3,5 | |
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Application Number
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